Integrated Vehicle-Based Safety Systems (IVBSS) Initiative

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What is the IVBSS Program?

- University of Michigan Transportation Research Institute (UMTRI)-led cooperative agreement with U.S. Department of Transportation (DOT)
  - National Highway Traffic Safety Administration (NHTSA) and Federal Motor Carrier Safety Administration (FMCSA)
- Develop integrated crash warning systems in light vehicles and heavy trucks to estimate safety benefits and driver acceptance
- 54-month, 2-phase, $32.2M program
  - $25M from U.S. DOT, $7.2M from the partners
IVBSS Phase I and II

• Phase I (Years 1 and 2)
  – identify crash problem (develop scenarios)
  – functional requirements
  – system performance guidelines
  – develop and conduct verification tests (test track and on-road)

• Phase II (Years 3 and 4)
  – build vehicle fleets and verify performance
  – conduct extended pilot test
  – conduct field operational test of ten trucks
IVBSS Subsystems

• Forward crash warning
  – Address rear-end crashes

• Lateral drift warning
  – Address lane/road departure crashes

• Lane change/merge warning
  – Address lane change crashes
IVBSS Partnership

Solid lines indicate subcontracts and working relationships
Dashed lines indicate working relationships only (no contracts)
Heavy Truck Platform
Overview

• Design, develop, verify and implement in heavy trucks an integrated crash warning system that addresses:
  – Rear-end crashes
  – Lane departure crashes
  – Lane change/merge crashes

• It will appear to drivers as a single system with an associated, integrated Driver Vehicle Interface (DVI)
Scope of IVBSS
Requirements

• Autonomous system
• No active vehicle control
• Technologies must be available for field operational test (FOT)
Systems Engineering

- Sensor descriptions
  - Tractor-only solution
- Subsystem descriptions
- Driver Vehicle Interface
- Objective Testing
Heavy Truck Sensor Suite

Radar and Vision Sensor Key:
- R: Rear Radar Sensor
- S: Side Radar Sensor
- F: Forward Radar Sensor
- V: Short Range Vision Sensor
LCM Concept of Operation

• Provides side object presence indicators to the driver and warnings of unsafe maneuvers
• Directional side visual display and directional auditory display
• Consistent with LDW warning display
• Combination of MA/COM radars and Backspotter radars
## LCM General Operation

<table>
<thead>
<tr>
<th>Cond. Code</th>
<th>Initiation Condition</th>
<th>Visual Displays</th>
<th>Auditory Display (Directional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCM-0</td>
<td>No vehicle detected adjacent to subject vehicle</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>LCM-1</td>
<td>Adjacent vehicle detected (use caution)</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>LCM-2</td>
<td>Adjacent vehicle detected AND corresponding turn signal is active AND lane change maneuver NOT detected</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>LCM-3</td>
<td>Adjacent vehicle detected AND lane change maneuver IS detected</td>
<td></td>
<td>Right/Left channel side collision warning</td>
</tr>
</tbody>
</table>
LDW Concept of Operation

• Track lane boundaries
• Measure vehicle position and lateral velocity relative to lane
• Assess threat of lateral departure to warn driver when they are about to depart lane.
### LDW General Operation

<table>
<thead>
<tr>
<th>Initiation Condition</th>
<th>Visual Displays</th>
<th>Auditory Display</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal Driving - Good boundaries</strong></td>
<td><img src="image1" alt="Visual Display" /></td>
<td>None</td>
</tr>
<tr>
<td>Vehicle maintaining lane position, nothing nearby, good marker on both sides.</td>
<td><img src="image2" alt="Visual Display" /></td>
<td><img src="image3" alt="Auditory Display" /></td>
</tr>
<tr>
<td><strong>Normal Driving - Missing left boundary</strong></td>
<td><img src="image4" alt="Visual Display" /></td>
<td>None</td>
</tr>
<tr>
<td>Vehicle maintaining lane position, nothing nearby, good marker on right, missing marker on left.</td>
<td><img src="image5" alt="Visual Display" /></td>
<td><img src="image6" alt="Auditory Display" /></td>
</tr>
<tr>
<td><strong>Departure into Clear Space</strong></td>
<td><img src="image7" alt="Visual Display" /></td>
<td>Directional lane excursion warning</td>
</tr>
<tr>
<td>Lane departure in the absence of object in adjacent region. Turn signal off, dashed or solid lane boundary</td>
<td><img src="image8" alt="Visual Display" /></td>
<td><img src="image9" alt="Auditory Display" /></td>
</tr>
<tr>
<td><strong>Departure into Occupied Space</strong></td>
<td><img src="image10" alt="Visual Display" /></td>
<td>Directional side collision warning</td>
</tr>
<tr>
<td>Lane departure with object detected in adjacent region. Dashed or solid lane boundary.</td>
<td><img src="image11" alt="Visual Display" /></td>
<td><img src="image12" alt="Auditory Display" /></td>
</tr>
</tbody>
</table>
FCW Concept of Operation

• Includes both a headway warning system and an imminent collision detection system
• Provides drivers with graded cautionary warnings when headway time to a forward object drops below four established threshold levels
• Provides collision warnings whenever a significant risk of collision is detected
## FCW Warning Logic

### Detection & Headway Alerts

<table>
<thead>
<tr>
<th>Code</th>
<th>Initiation Condition</th>
<th>Forward Display</th>
<th>Auditory Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCW-1</td>
<td>Forward object detected</td>
<td><img src="#" alt="Forward object detected" /></td>
<td>None</td>
</tr>
<tr>
<td>FCW-2</td>
<td>Forward object within 3s headway (and no higher priority alert) AND opening OR closing</td>
<td><img src="#" alt="3 seconds" /></td>
<td>None</td>
</tr>
<tr>
<td>FCW-3</td>
<td>Forward object within 2s headway (and no higher priority alert) AND opening OR closing</td>
<td><img src="#" alt="2 seconds" /></td>
<td>Opening=None Closing=Short Alert</td>
</tr>
<tr>
<td>FCW-4</td>
<td>Forward object within 1s headway (and no higher priority alert) AND opening OR closing</td>
<td><img src="#" alt="1 sec" /></td>
<td>Opening=None Closing=Double Alert</td>
</tr>
</tbody>
</table>

**Note:** Headway alerts provided when SV speed is greater than 10 mph
# FCW Warning Logic

**Collision Alerts**

<table>
<thead>
<tr>
<th>Code</th>
<th>Initiation Condition</th>
<th>Forward Display</th>
<th>Auditory Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCW-5</td>
<td>Forward object within 0.5s headway AND closing</td>
<td><img src="image1" alt="Collision Alert" /></td>
<td>Repeating Alert</td>
</tr>
<tr>
<td>FCW-6</td>
<td>Slow moving vehicle alert</td>
<td><img src="image2" alt="Collision Alert" /></td>
<td>Repeating Alert</td>
</tr>
<tr>
<td>FCW-7</td>
<td>Stationary vehicle/object alert</td>
<td><img src="image3" alt="Collision Alert" /></td>
<td>Double Alert</td>
</tr>
</tbody>
</table>
Arbitration

- Develop a rule-based approach
  - use simple ratings of message priorities to support rule development
- More complex rules and exceptions to the rules requires taking into account:
  - vehicle kinematics
  - cues to driver alertness
  - indications of driver awareness of the threat
  - crash risks
DVI Concept of Operation

• Focus is on supporting a timely and appropriate response from the driver
• Integration should support the development of an accurate and functional mental model of the IVBSS
• Support the driver in avoiding errors, distraction, confusion, and information overload
• Heavy truck drivers are significantly different than passenger car drivers—they have formal training
Development Process – Heavy Truck Platform

Customer Inputs (Assumed/Actual)

- Crash Problem
- Driver interaction assumptions
- Driver interaction research

Crash scenarios
Operational (do-not-warn) scenarios

Functional Requirements
- Performance Guidelines
- Design specifications
- Objective Test Procedures

Vehicle Releases
Verification Testing
FOT build

Technology Assumptions

Indicates public document is, or will be, available
Objective Testing Truck Setup

Sensor/Camera Locations

- Rear-looking M/A-Com radars
- Forward-looking AC20 radars
- Backspotter radars
- Forward-looking camera
Track Tests

Rear-end verification Tests

2.1 Rear End with constant speed P1
Test 1 RE slowing 20 km/h

2.2 Rear End with slowing P1
Test 2 RE slowing 50 km/h

2.3 Rear End with Stopped P1
Test 3 RE with Stopped ROV cycle

2.9 Rear End with Slower Moving Motorcycle

Multiple Threat, On-Road, & No-Warn

Lane-Change Verification Test Guidelines

3.1 Lane Change into Adjacent P1
Test 15 RE 50 km/h & exceeding app ROV cycle
Vehicle speed 80 km/h

3.3 Lane Change into adjacent P1 vehicle on Merge

3.5 Lane Change into Approaching P1 vehicle

Road Departure Verification Test Procedures

4.1 Road Departure toward Opposing Traffic Lane
Test 16 RE 50 km/h & exceeding app ROV cycle
Vehicle speed 100 km/h

4.2 Road Departure Toward Clear Shoulder

4.3 Road Departure Toward Clear Shoulder on Curve

4.5 Road Departure Toward Curve with Excessive Speed
Phase II – Early Tasks

- Complete final vehicle integration design
- Launch vehicle fleet builds
- Integrate final FOT data acquisition system
- Tune system further to reduce false alerts
Heavy Truck (HT) FOT Scope

- Testing will occur over a ten month period
- The volume of data would represent approximately 8 years of HT driving data
- A data server will be installed at the HT fleet distribution center
  - Approximately 600GB of data expected
Fleet Location

- FOT will be run out of Con-Way Freight’s Romulus, MI terminal
  - Includes MI’s lower peninsula, northern Ohio/Indiana, and Chicago
  - Local P&D is 41% limited access highway
  - Line-haul is 96% limited access highway
  - Estimated total mileage exposure for FOT fleet is 82% limited access, 18% service roads
- Driver age is from 25–65 (all male)
Heavy Truck FOT Data

- Subjective data
  - Questionnaires, focus groups, debriefings

- Objective data
  - Multi-CPU DAS that is unobtrusive
  - Full-time dataset describing:
    - Vehicle performance
    - Driver performance
    - Vehicle location
    - Driving environment
FMCSA’s Role

• Assure safety of commercial heavy trucks
  – encourage deployment of safety equipment that is deemed beneficial to heavy truck safety
  – assure safety is not adversely affected by overloading heavy truck operators with information

• Assure IVBSS accounts for unique requirements of operating heavy trucks
  – e.g., headway information critical for heavy truck drivers due to evasive capabilities
Program Status

• Completed Phase I
  – HT systems passed verification tests
• Public meeting on results in April 2008
• Phase II kickoff meeting held in June 2008
• Track and on-road tests completed in October 2008
• Extended pilot test to start in November 2008
• Field operational test to start in early 2009
Contact Information

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